Low-Probability High-Consequence Risk Analysis

Issues, Methods, and Case Studies

Edited by

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Los Alamos, New Mexico

and

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Oak Ridge National Laboratory

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RESIDENTIAL PROXIMITY, PERCEIVED AND ACCEPTABLE RISK*

George O. Rogers

University Center for Social and Urban Research
University of Pittsburgh
Pittsburgh, Pennsylvania

ABSTRACT

The perception of risk and the acceptance of it are partially a product of life experiences. This occurs because "ordinary-knowledge" is principally comprised of experiences, and the perception and acceptability of risk rests firmly upon that "data bank" of knowledge. Hence, life-experience is inherently related to perceived and acceptable risk. This paper focuses on the relationship between the life experiences associated with residential proximity, and the perception and acceptability of the risks associated with generating electricity in nuclear power plants. Perceived risk is operationally defined in terms of estimated likelihood of occurrence, while acceptability of nuclear power is defined in terms of people's favorable or unfavorable opinions regarding nuclear power plants. In the context of a simple social-structural model of perceived and acceptable risk, four potential explanations for enhanced acceptability among those residentially proximate with nuclear facilities are examined: 1) Residents, through the experience of living with hazard, are reinforced toward assigning lower probabilities to the potential risks associated with nuclear facilities. 2) The cognitive dissonance created by the acceptance of the risks

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associated with nuclear power is decreased by reducing perceived risk. 3) Nuclear neighbors are predisposed toward, educated about, and/or economically dependent upon nuclear power hence the more favorable attitudes toward it. 4) Nearby residents are systematically more altruistic -- other oriented -- than the general population and thus more willing to bear the risks associated with nuclear power. Low-probability/high-consequence risks are sometimes assessed in terms of revealed societal preferences. However, assessing risk in this manner without careful consideration of social processes involved is somewhat superficial and misleading. In this sense, a more complete understanding of the social processes involved in the perception and acceptability of risk is essential. The examination of these four hypotheses provides a foundation on which such an understanding may be established.

KEY WORDS: Perceived Risk, Acceptable Risk, Life-experience, Residential Proximity, Lay-estimation, Lay-evaluation.

INTRODUCTION

The perception and acceptability of risk are partial functions of life-experience. This occurs because "ordinary-knowledge" is principally comprised of experiences, and the perception and acceptability of risk rests firmly upon that "data bank" of knowledge. The cognitive processes, through the use of heuristics [1], utilize this "data bank" of experience in estimating risk and assessing its acceptability. This paper seeks to examine the relationship between perceived and acceptable risk and life-experience. Persons of differing social background have varying experiences. Further, even identical experiences will have different meaning to persons of varying social position. The experience of living with hazard becomes the primary focus of this research. It is investigated in the context of a simple social-structural model of the perceived and acceptable risks associated with the production of electricity in nuclear power plants and perceived likelihood of nuclear attack.

It has been recognized for some time that the general public finds nuclear power plants more acceptable in general terms than when asked about locating such facilities in their own vicinity [2-5]. This location near one's community is thought to elicit stronger, more "instinctive" responses among the populace [4]. However, evidence shows that persons residing near extant nuclear facilities find producing electricity in nuclear power plants more acceptable than the general public [2-5]. From this apparent paradox arises the primary impetus for this research: What is it about living with low-probability/high-consequence hazards that makes them more acceptable?

Risk assessment is conceptually cast as hazard identification, involving the reduction of uncertainty through recognition: risk estimation, consisting of the measurement of risk potential; and risk evaluation, involving the determination of the social acceptability of risk [6-8]. While these concepts are prevalent among risk analysts, there is no a priori reason to believe that lay-people define risk differently. In fact, it may be posited that lay-people utilize a similar, though perhaps less sophisticated, less quantified, or less rigorous, parallel system of evaluation [9]. The lay-system treats hazard recognition as a lay identification of hazard, perceived risk being a lay estimation, and attitudes bearing on acceptability representing a social evaluation of risk. Hence, the public assesses risk through an assessment process that roughly parallels (at least in character) the process used by experts. This, of course, does not imply that the results are or need be similar. Often wide diversity has been demonstrated [10]. This is also evidenced in the public's response to risks of various kinds. Revealed social preferences, as manifested by behavior, show themselves as willingness to live with some existing risks. To an extent, they can be used as evidence of social acceptability of risks of various kinds [8, 11]. An understanding of the social processes involved in the lay assessment of risk is essential, both in terms of projecting acceptability into the future, and in order to make extensions from one risk to another.

Attitudes and perceptions (and thus expressed preferences) of a hazard play a significant role in determining actual response when a risk is actualized [12, 13]. It is known that preconceived images of disaster are often at considerable variance with what may be shown through careful, systematic, objective social science observation [14]. It has also been stressed that, for example, panic behavior is considerably affected by these images [15]. Inasmuch as the mass media play a predominant role in the development and maintenance of these images, and risk in general (catastrophic risks such as those associated with nuclear power are issues that "enjoy" the media limelight), it is not surprising that the general public considers the risks associated with nuclear power plants more extreme than many other hazards [10].

BACKGROUND

Since Chauncey Starr's [16] early work on social benefit and technological risks, risk analysts have tended to concentrate upon the characteristics of risks. This research is very important with regard to the understanding of the cognitive processes involved in the perception and acceptability of various types of risk. However, this distinction is often blurred [10, 17, 18]. Through careful examination of insurance records and safety surveys Slovic, Fischhoff, and Lichtenstein [19] suggest that the public seems to be more sensi-

tive to likelihoods than to severity in judgments concerning risk. Perceived risk may be defined, as Lowrance [17, 18] prefers, as a function of the likelihood and magnitude of potential harm -- the lay-estimation of risk. Risk evaluation, which establishes the social meaning of risk, may be cast in terms of worry, concern, dread, anxity or angst [20]. The perception of risk is operationally defined as the lay-estimation of likelihood, while acceptability attitudes, which bear on the social evaluation of risk, are operationalized in terms of favorableness.

The American people are favorably disposed, by factors of two or three to one, toward the production of electricity in nuclear facilities [2-5, 21]. Furthermore, this support remains high in response to items concerning the acceptability of nuclear power plants "nearby" [2-5, 21]. However, the support for "nearby" facilities is generally lower than is support for nuclear power plants "around the country." Such findings suggest that the general public finds nuclear power plants "located elsewhere" more acceptable than plants in their own vicinity. Americans, therefore, recognize a need for utilizing nuclear energy in the production of electricity, though they would prefer the risks be borne by others [2-5, 21]. At the same time, people residing near existing nuclear facilities [2-4, 22] tend to find nuclear power plants and the construction of additional nuclear facilities more acceptable than does the general public. Inasmuch as the principal population at risk is comprised of "nuclear neighbors," this finding seems to be counter to what common sense would suggest [21].

Residential proximity apparently relates to more favorable disposition regarding the generation of electricity in nuclear power plants. If one assumes that perceived and acceptable risk are inversely related (a fact that is empirically verified by this research), several possible explanations are suggested. Nehnevajsa [21] highlights two. First, nuclear neighbors tend to "fool themselves" into believing nuclear power plants are less hazardous by "wishing away," "thinking away," or "suppressing" the potential for hazard realization. Second, a recognized "...history of accident-free operations, ... tends to induce a conclusion on the part of most people that the processes of nuclear power production are rather 'safe' or at minimum, not as 'unsafe' as the opponents of nuclear energy proclaim" (p. 151). The first explanation implies that "nearby" residents of such a hazard reconcile the possible dissonance between likelihood and acceptance by altering their likelihood estimation, that is, by lowering it [23]. The second explanation posits that because of the experience of living with the potential hazards associated with nuclear facilities on a daily basis, and the inherent low-probability of an accident, "nuclear neighbors" are reinforced [24, 25] toward lower likelihood estimates, thereby increasing the acceptability of risks associated with nuclear facilities.

Perceived risk and acceptable risk are inversely associated. "...the more the perceived risk, the lower the favorability toward nuclear power" [21:p. 150]. Hence, both the cognitive dissonance explanation and the experience of living with hazard explanation imply that persons subjected to hazard, through residential proximity, reduce their estimations of the hazards involved, either to "meet" the associated acceptability or to "justify" it. In Nehnevajsa's [21: p. 150] terms, one possible explanation is that:

> ...the perception of risk causes disaffection from the nuclear option. In other words, people do not support nuclear energy because of the perceived dangers associated with it.

The other explanation suggests that:

> ...people may dislike nuclear energy for whatever reasons, such as its weapons-related historical roots, and justify their position by perceived riskiness. In other words, nuclear power generation systems are then seen as risky because nuclear power itself is disfavored for whatever reasons. (Emphasis added).

However, if perceived risk is either increased or remains unassociated with residential proximity, two additional explanations are suggested.

First, a group of Battelle researchers [4] suggests that any interpretation of nuclear neighbor acceptance of nuclear facilities must inherently be tempered by three considerations. First, power plants, in the siting process which precedes their construction, end up in locations where dispositions are more favorable to begin with -- predisposition, second, an announcement of the selection of the site and its construction is usually accompanied by considerable public relations, educational material, and activity on the part of utility interests -- education. Third, some residents may have been attracted to the area in seach of employment (either in the facility itself or in supporting operations) when attitudes are assessed during or after the construction of the facility -- economic dependence.

Second, residents of the hazard zone, through self-selection, training, knowledge, information, inclination, or economic dependence, may use different standards in their assessment of the associated risks. Rankin and Nealy [22] have indicated that people with pro-nuclear attitudes are more likely to have value-systems that are similar to those of the "average American." People living near nuclear facilities, who are the most pro-nuclear group examined by Ranking and Nealy, place greater importance on family and national security, and less importance on a world of beauty and equality, when compared with environmental activists. This could be viewed as embodying a concern for society. To the extent that the risk is either necessary or unavoidable, residing in the vicinity can be viewed as "for the good of the whole." These values repre-

sent, among other things, a degree of "other orientation." In this sense, altruism may be defined as the propensity for action, considering the interests of others, without ulterior motives [26]. It is not argued here that specific others need be considered; instead, the consideration of society is sufficient. This, together with concerns for the family and national security, reflects a certain altruism. Hence, nuclear neighbors recognize the risks associated with nuclear power plants and choose to accept them for the "good of the whole."

The relationship between enhanced acceptability and residential proximity may be an admixture of these alternative explanations. This research examines the degree to which each explanation is relevant in the context of the social structural model, which accounts for the effects associated with age, sex, and education.

METHODOLOGY

A simple model of social structural characteristics, residential proximity, perception and acceptability of risk is developed. Due to their prominence in the status literature [27-30] and their consistent relations with attitudes concerning nuclear power [4, 31, 32] and risk in general [33], the social structural characteristics of age, sex, and education are selected as the structural components of the model. Residential proximity is operationalized both subjectively in terms of respondent recognition of residential proximity, and more objectively in terms of actual geographical proximity with nuclear power plants [34] and nuclear attack targets [35]. Living in objective proximity with a nuclear power plant is defined as being a resident within 50 miles of an existing or planned nuclear facility, while objective proximity to high risk areas of potential nuclear attack is defined in terms of residential proximity with military and industrial installations, using the Defense Department's TR-82, High Risk Areas.

Objective residential proximity is defined by geographic location of sampling points in the 1978 national survey on issues of civil defense [5]. This process involves the location of sampling points relative to both nuclear power plants and expected targets of nuclear war. These geographical areas partially in the risk areas are considered "at risk." In the case of nuclear power plants, objective and subjective residential proximity are compared by sample point to determine the "reasonableness" of the objective residential proximity code. If the sampling point was partially "at risk," and a high degree of incongruence between objective and subjective proximity existed, subjective proximity was accepted. This procedure assumes that it is unlikely that large proportions of people living near a specific nuclear facility would "misjudge" their residential proximity. However, even in instances of high

incongruence between objective and subjective residential proximity, if the sampling point was clearly within 50 miles, objective proximity was used. Subjectively defined proximity was allowed in relatively few cases and is not thought to affect the relationships presented in the model or between subjective and objective residential proximity in any appreciable manner.

The data utilized in this research stem from a 1978 national survey of 1620 non-institutionalized adult Americans (18 years of age or older residing in the 48 contiguous United States) concerning the many salient issues of civil defense [5]. The sample is a national probability sample with a ±3% sampling error at the regional level, and a ±1.7% sampling error nationally, at the .95 confidence level. This survey casts perceived and acceptable risk in terms of lay-estimated likelihood of nuclear war and nuclear power plant accident, and favorableness associated with nuclear power "nearby" and "around the country."

A series of log-linear models are fit to contingency tables using these data [36-39]. This analytic technique is appropriate for cross-classified or contigency data. It essentially searches for a set of subtables that when "fit" account for systematically patterned variation in the contingency tables. This technique allows the researcher to systematically account for variation in the contingency tables and isolate specific associations in the context of the model. It is through this analytic technique that four explanations for the enhanced acceptability of risk among nuclear neighbors are examined. Actual analysis was conducted using BMDP Biomedical Computer Programs: P-Series software package [40] using program P3F.

HYPOTHESES

Living near a nuclear power plant is related to a more favorable disposition toward nuclear power [2-4, 21, 22]. Both the cognitive dissonance and the experience of living with hazard explanation, suggest that perceived risk is lower for nuclear neighbors than for the general public. When low-probability hazards are considered, residential proximity tends to reduce the level of perceived risk. The recognition of residential proximity with the hazard(s) is essential in the creation of the cognitive dissonance, which is "minimized" through the lowering of the perceived likelihood. Hence, those persons that fail to recognize their residential proximity would not adjust perceived risk in achieving a closer congruence between perceived and acceptable risk. On the other hand, the experience of living with hazard explanation also rests, to a certain degree, upon recognition -- although less so than the cognitive dissonance explanation. This occurs because it is possible to accumulate experience, by recognizing historical safety records, without

actually living in relative proximity with the hazard. Actual residential proximity, without recognition, has no effect on perceived risk. This will be examined in the nuclear power plant context of support for nuclear power plants "around the country" and for having a power plant "nearby." In addition, this hypothesis will be examined in terms of likelihood of power plant accident and likelihood of nuclear war. These two risks appear quite similar in terms of likelihood or perception, yet they are substantially different in terms of potential recognition of proximity. While nuclear power plants are physically identifiable, targets of nuclear war are less obvious and much less "certain." Hence, recognition of residential proximity is more difficult for the nuclear war hazard than for those associated with nuclear power plants. This means that the cognitive dissonance process is more difficult to operationalize for the nuclear war hazard. But examination of actual and perceived residential proximity in these contexts provides some clues to evaluate the alternative explanations.

The relative favorable predisposition of residents in the area near a plant would suggest that nuclear neighbors, regardless of the stage of development associated with the plant in their area, would vary only minimally in their attitudes toward or about nuclear power. Inasmuch as educational activities on the part of utility interests are concentrated in the early stages of selection and development of a site, attitudes bearing on the perception and acceptability of the risks associated with nuclear power would exhibit minimal variation. Finally, because a considerable work force is involved in the construction and operation of nuclear facilities, minimal variation in attitudes concerning nuclear power is expected among plants at different stages of development. Predisposition, educational activities, and economic dependence of people residing near nuclear facilities would be roughly equal, irrespective of the stages of development associated with the plant. Hence, perceived residential proximity with nuclear power plants at various stages of development does not affect the perception or acceptability of risk. This hypothesis suggests that if there are no significant differences associated with residing near planned or existing facilities, the predisposition-education-economic explanation is the predominant explanation for the relationship between perceived and acceptable risk and residential proximity.

The altruistic explanation suggests that nuclear neighbors hold value-systems that support an "other orientation" to a higher degree than the general public. If this explanation holds true, nuclear neighbors would also be more likely to accept evacuees into their homes under emergency conditions, volunteer for service, and may even have a history of volunteering behavior. Residential proximity is directly associated with altruistic behaviors and attitudes. This may be examined for both nuclear power attitudes "around the country" and "nearby."

FINDINGS

In each log-linear model concerning nuclear power plants both "around the country" and "nearby," the relationship between lay-estimated likelihood of accident and favorability of nuclear power is inverse -- the greater the perceived likelihood of accident, the less favorable nuclear attitudes concerning nuclear power. By all tests, this association is a robust one. Respondents that estimate the likelihood of an accident as "likely" or "very likely" are 18 to 20% less likely to find nuclear power plants acceptable than persons not estimating the chances of an accident as "likely" or "very likely." In each model, the relationship is somewhat stronger in the "nearby" representation of favorability. The estimates of the association are at or near the 20% level in the "nearby" model, while the estimates of the same effect are at or near the 18% level in the "around the country" models. These findings hereby confirm empirically Nehnevajsa's [21] work and our assumption that risk perception and risk acceptability are inversely associated.

In the first conception of residential proximity, both perceived and actual residential proximity are included so that objectively being at risk and recognition of hazard proximity may be compared. In each model objective proximity is robustly associated with perceived residential proximity. Being geographically or ecologically located near existing or planned nuclear facilities increases by around 30% the likelihood that this proximity will be recognized. Furthermore, as suggested by the nature of the risks, objective residential proximity with targets of nuclear war enhances the likelihood of perception of residential proximity by only around 18%. Even this association appears to be quite strong. Actual residential proximity is not significantly associated with any other factor. Hence, it is empirically suggested that perceived proximity, irrespective of actual residential proximity, plays the important role in perceived and acceptable risk.

Perceived residential proximity, both in terms of with existing and planned nuclear power plants, is not associated with the lay-estimated likelihoods of accident in any model. Regarding the likelihood of nuclear war, however, perceived proximity is positively associated with the "likely" or "very likely" response. When compared with nuclear power, recognizing the targets of nuclear war is empirically and conceptually more difficult. This together with the association between perceived proximity and estimated likelihood suggests that it is highly unlikely that the cognitive dissonance explanation plays any appreciable role. Thus, the relationship between residential proximity and the degree to which the risks associated with nuclear power are perceived and found acceptable is probably not a function of cognitive dissonance.

In each model, concerning nuclear power plants both "around the country" and "nearby," and regardless of the conception of resi-

dential proximity being employed, persons living near existing nuclear power plants are more favorably inclinded toward nuclear power than those residing elsewhere. Persons recognizing their residential proximity with nuclear facilities tend to favor nuclear power in general, being about 6% more likely to favor nuclear power "around the country" than non-residents. Furthermore, nuclear neighbors even more strongly favor nuclear power plants in their own vicinity, being about 18% more likely to favor plants "nearby" than non-residents. This confirms the direct relationship between residential proximity and underlying support for nuclear power.

When residential proximity is cast in terms of both planned and existing facilities combined, there is no apparent relationship between residential proximity and estimated likelihood of accident. However, changing the conception to treat perceived proximity with planned and existing nuclear facilities separately, shows that perceived residential proximity to existing facilities reduces the estimated likelihood of accident. The estimated effect is not significant at the .05 level, when attitudes about facilities "nearby" are considered. On the other hand, perceived proximity with planned facilities tends to increase the estimated likelihood of accident. This relationship is significant when either attitudes "around the country" or "nearby" are considered. A degree of apprehension, with respect to having a plant "going in around here," seems to be reflected in this relationship.

Residential proximity with planned facilities has negative, albeit non-significant, effects on nuclear power attitudes for both "around the country" and "nearby" indicators. However, persons residing near existing facilities are about 16% more likely to favor nuclear power "around the country" and 29% more likely to favor facilities "nearby" than non-residents. These findings: a) the relationship between proximity to existing plants and perceived likelihood of accident is relatively weak; b) the association between favorability and residential proximity is relatively strong; and c) the "around the country" and "nearby" indicators of favorability establish a directional pattern of response; suggest that d) the experience of living with hazard explanation alone plays a relatively minor, although non-negligible, role in the explanation of the overall relationship between residential proximity and perception and acceptability of risk.

Residential proximity with existing and planned facilities reflect markedly different patterns of association with perceived and acceptable risk, both in terms of the direction and the magnitude of effect. Perceived proximity to existing nuclear power plants enhances favorability by about 16% for the "around the country" and 29% for the "nearby" model. Nuclear neighbors (with existing facilities) are also around 10% less likely to respond that an accident is either "likely" or "very likely," when compared to non-

residents. Perceived proximity to planned facilities, on the other hand, has a negative, albeit non-significant association with favorability. Recognizing residential proximity to planned power plants increases, by about 20%, the probability of responding that an accident is either "likely" or "very likely." Since the response pattern of persons believing they reside near planned and existing facilities is at variance, both in terms of favorability and likelihood estimates, the predisposition-eduction-economic explanation is not thought to be the principal explanation. However, the favorable inclinations associated with residing near existing facilities, together with the findings of Nealy and Rankin [41] that nuclear neighbors tend to be more informed about nuclear power than the general public, suggest that the predisposition-education-economic explanation cannot be entirely disregarded.

Altruistic attitudes are positively associated with attitudes concerning nuclear power plants "around the country" and "nearby." People expressing intentions to volunteer for civil defense and shelter evacuees are about 10-12% more likely to "favor" or "strongly favor" nuclear power "around the country" and "nearby" than persons not expressing such intentions. However, the association between volunteering for civil defense and nuclear power favorability "nearby" is not significant at the .05 level. While there is no association between reported volunteering behavior in the previous year and favorability "around the country," such an association is present for the "nearby" model, with persons that have volunteered in the previous year being around 6% more likely to "favor" or "strongly favor" nuclear power plants "nearby" than are either nonresidents, or those not prone to volunteer. Hence, altruistic tendencies are associated, if at all, in a direction inconsitent with the altruistic explanation.

CONCLUSIONS

To the extent that: a) the general public uses a similar conceptual process, although with less rigor and sophistication and certainly with different results, in the evaluation of risks as the process adopted by risk analysts; and b) the general public's preferences are to be incorporated in the formation of public policy concerning risks of various classes; a clear understanding of the social processes involved in the public assessment of risk is essential. Extending risk assessments from one risk to another, or even one situation to another, is markedly more difficult without a clear understanding of these processes.

The direct association between residential proximity and enhanced acceptability with regard to the hazards associated with nuclear power has been examined in terms of four potential explanations for the relationship. The cognitive dissonance explanation,

which posits that enhanced acceptability is a function of reconciling a "forced" acceptance and a relatively high perceived risk, was not supported. Inasmuch as no overwhelming support for decreased lay-estimation of risk among those in residential proximity with nuclear facilities is evidenced, it could be suggested that persons residentially proximate are more altruistic than others -- that is, prone to act in full consideration of others. However, persons that reside near nuclear facilities and that are prone to altruism, tend not to favor nuclear power, which is inconsistent with the altruistic explanation. Hence, both the cognitive dissonance and altruistic explanations are unequivocally rejected.

While persons residing near nuclear facilities are certainly more favorably inclined toward nuclear power plants, both "around the country" and "nearby," they estimate the chances of an accident at levels very similar to those of others. However, when proximity with existing and planned facilities are treated separately, some small differences are apparent. Hence, there is relatively weak support for the explanation that posits that nuclear neighbors are positively reinforced toward lower perceived risk through living with the non-realized risks associated with living nearby. In addition, however, we were unable to disregard the notion that nearby residents could be predisposed toward nuclear power plants, more informed about any associated risks and/or benefits, or enjoy (or perhaps know someone who enjoys) the economic benefits of nuclear power (perhaps even in terms of dependence upon). Hence, we suggest that the living with hazard explanation may couple with the predisposition-educational-economic explanation to create a slightly reduced "sense of impending danger" and a greater sense of benefit among nuclear neighbors. This may be augmented by being residentially proximate to both the plant itself and the people who work there. Furthermore, the enhanced perception of benefit is more pronounced than the diminished perceived risk associated with the experience of residing near nuclear facilities.

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